U.S. ARMY TANK AUTOMOTIVE RESEARCH, DEVELOPMENT AND ENGINEERING CENTER (TARDEC)




Acquiring 21st Century Blitzkrieg via Physic-Based Gaming

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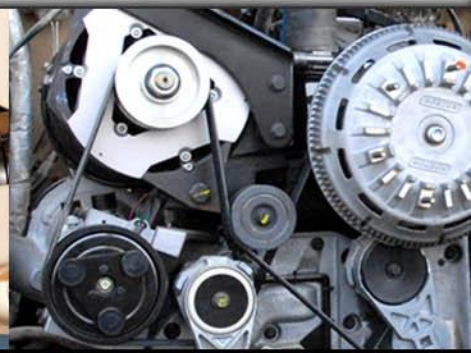

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14. ABSTRACT
Briefing Charts for GROUND VEHICLE SYSTEMS ENGINEERING AND TECHNOLOGY SYMPOSIUM (GVSETS), SET FOR AUG. 12-14, 2014

15. SUBJECT TERMS

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Agenda

- ESP in Systems Engineering
- Whole System Trade Analysis
- Defense Acquisition University MindRover/ Dragonfly
  - MAJ Keena's MindRover Tradespace Analysis
- Conclusions

BLUF

Finding the sweet-spot among competing objectives (performance, unit cost, O&S costs, development risk, and growth potential) is a non-trivial task. Ultimate metric is **affordable mission success**.

Ground vehicles are complex systems with many interrelated subsystems.

Materiel and Tactical Employment are not separable in real world.

Early Synthetic Prototyping

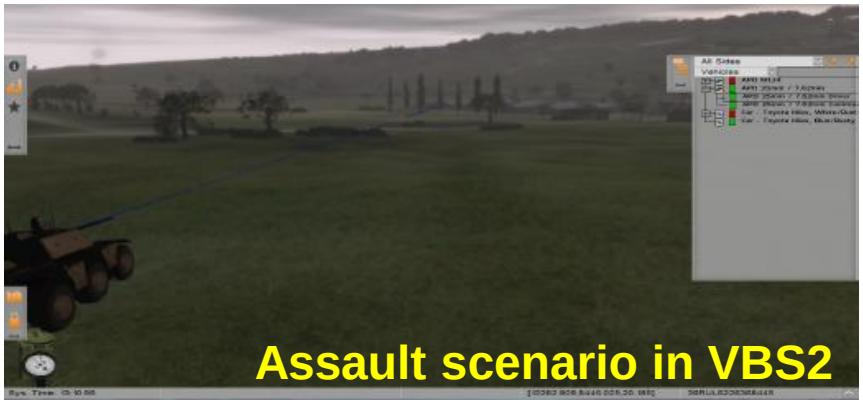
ARCIC Early Synthetic Prototyping (ESP)

- MG Hix tasked LTC Vogt to setup a persistent game environment for Soldiers to play emerging technologies.
  - ARCIC is looking for >20 year out concepts for the Army to try out in a gaming environment
  - End state: 1000 Soldiers in **persistent** environment
- Initially pursuing robotic wingman concept as pilot study
- First person shooter environment to start (VBS3 currently)

Random Fact: After one month of the release of Call of Duty Black Ops, gamers accumulated 68,000 years of play.

Early Synthetic Prototyping NPS Pilot Study: Robotic Wingman

- Robotic wingman based on actual demonstrator system
- Three scenarios:
  1. Track a red convoy (AI) to a specific location, then eliminate it. 4 blue
  2. Assault a defended, fixed location to free prisoners. 2 blue/ 2 red
  3. Defend an urban location for five minutes. 2 blue/ 2 red



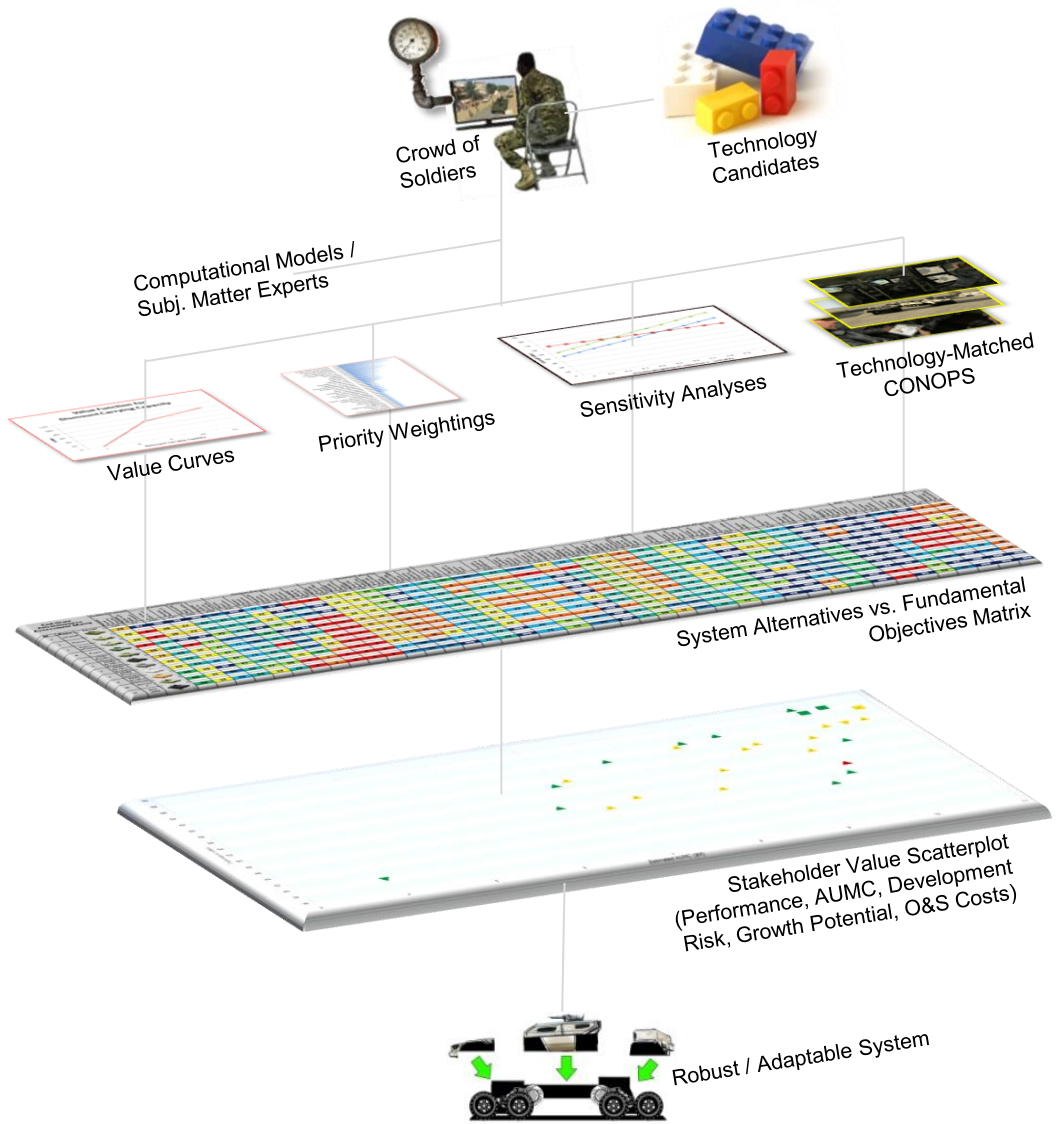
Game Physics Based on Autonomous Platform Demonstrator

Big Takeaways:

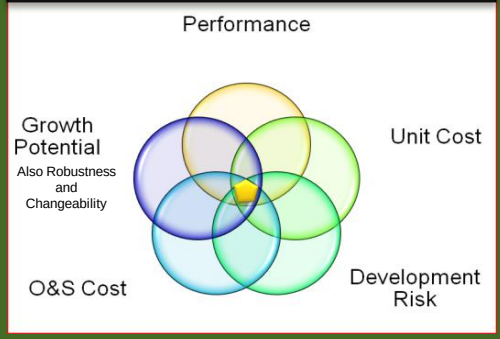
- Soldiers very enthusiastic about playing game – especially head-to-head
- Game interface is very important (which key does what)
- Scenarios showed definite desire to tailor platform for mission

Source: Early results from Naval Postgraduate School study (R. Darken and MAJ K Murray). Unclassified.

Early Synthetic Prototyping: Systems Engineering Construct

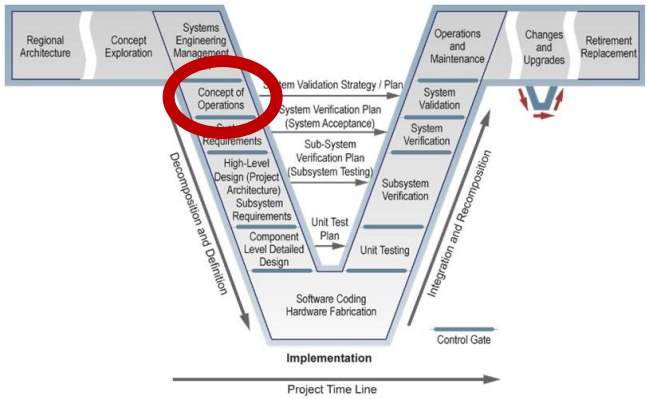


Elements of Stakeholder Value



Capture and synthesize analyses being conducted by Soldiers AND subject matter experts into visualizations designed to facilitate rapid and complete understanding of the trade-space to stakeholders and provide drill down capability to supporting rationale.

How do you develop a system if you do not know what it is supposed to do?



108 SE's surveyed:[1]

- 36% never had CONOPS
- 73% did not complete CONOPS by program start
- 50% did not update CONOPS
- 30% did not involve a user

60 CONOPS examined:

- took 3-30 months to complete
- 25% did not state mission needs
- 80% did not discuss system risks
- 50% did not include operational scenarios
- 50% of IEEE or ANSI standard elements were not included

NOTE: CONOPS = Concept of Operation

1. Roberts, N., & Edson, R. (2008). System Concept of Operations: Standards, Practices and Reality. NDIA Systems Engineering Conference, San Diego CA.
2. Cloutier, R. et al. (2009). Investigation of a Graphical CONOPS Development Environment for Agile Systems Engineering: Systems Engineering Research Center. SERC-2009-TR-003.

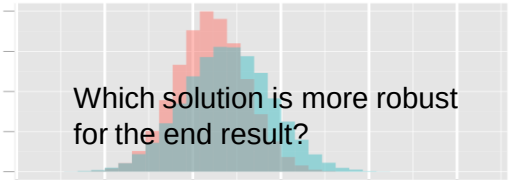
Value of Digital Combat vs. "Magazine Racing"

Magazine Racing: Where you pull out the specs and never run the race.

DATA Based: Maintenance, weather, driver tactics, trans type, component durability, run-to-run variation, etc

Camaro SS 2010
Engine: 6.2 Liter LS3
Power (SAE): 426 BHP @ 5900 RPM
Torque: 420 ft-lb @ 4600 RPM
Weight: 3,860 lbs

Mustang GT 2011
Engine: 5.0L V8
Power (SAE): 412 hp @ 6,500 rpm
Torque: 390 ft-lb @ 4,000 rpm
Weight: 3,605



NOTE : Performance specifications are notional. No particular company is endorsed.

Tactical Utility Concept

Major driver of **future** acquisitions is to maximize combat success at a minimal cost:

Tactical Utility = Mission Success / Total Cost

- Mission Success resiliency **quantified by game data**
- Total Cost = development, acquisition, future customization, maintenance, disposal

Future will bring tension between two extremes and solution robustness:

1. Mass produced, but adaptable / flexible via modularity
2. Custom specific purpose "disposable" vehicles

Closer Look at WSTAT Tradespace Exploration

Whole System Trade Analysis was developed by TACOM to identify relationship between high level design decisions & stakeholder value. Contact: Shatiel Edwards.

shatiel.b.edwards.civ@mail.mil

Example Stakeholder Value Scatter Plot Window

Legend

Development Risk

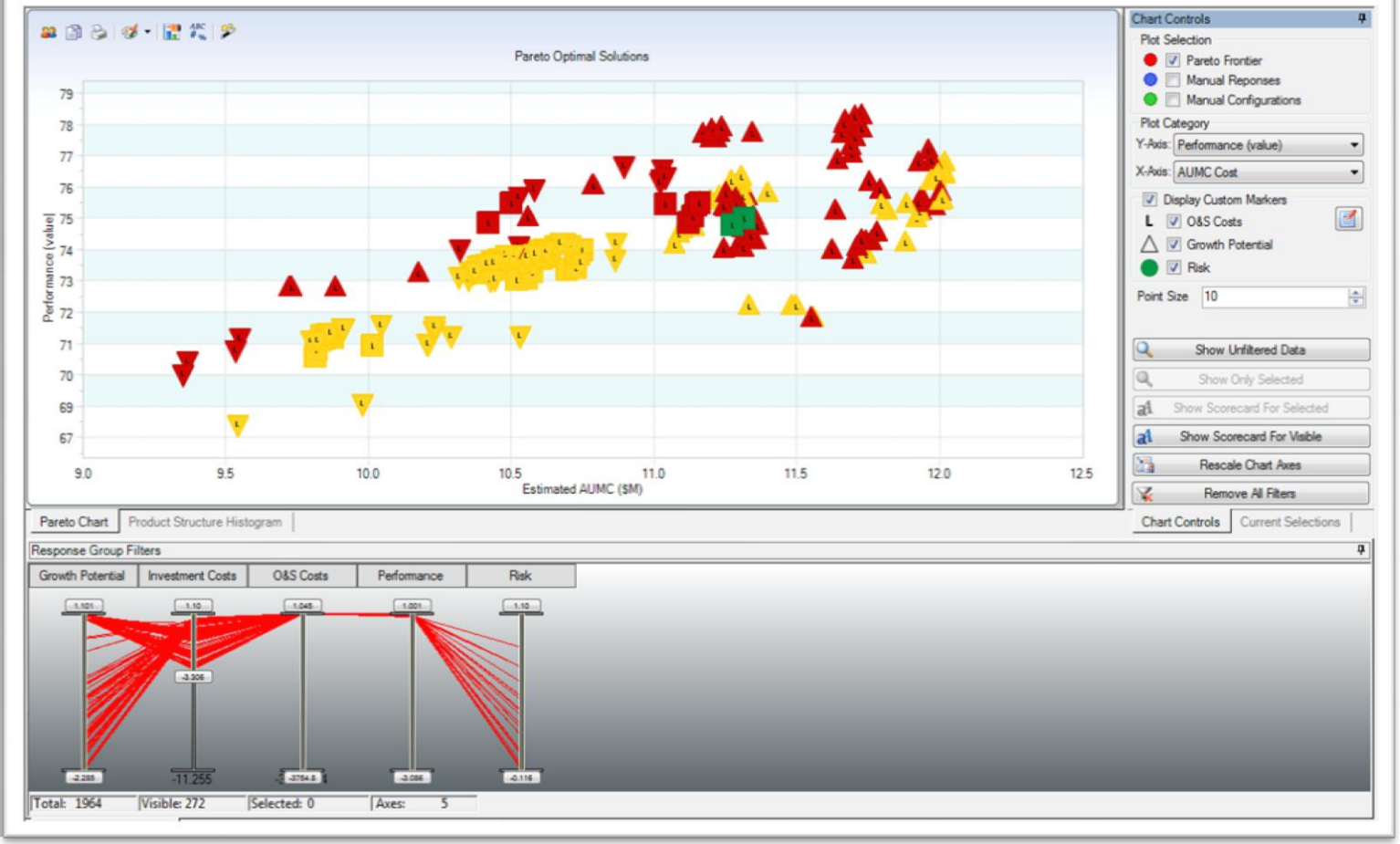
- High Risk
- Moderate Risk
- Low Risk

Growth Potential

- high growth potential
- moderate growth potential
- low growth potential

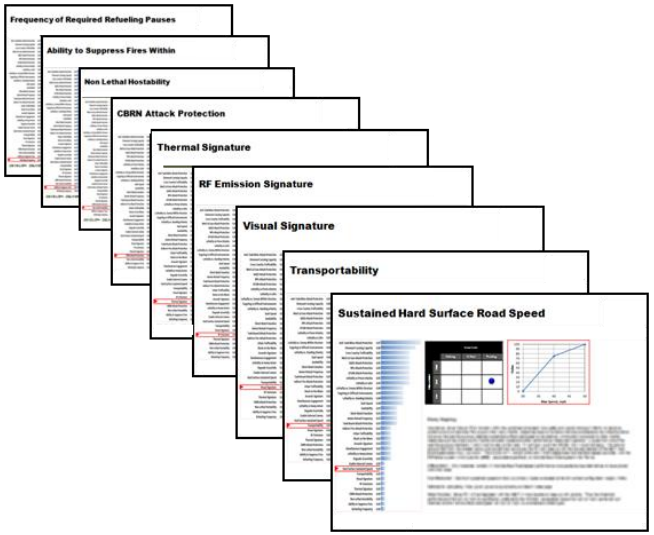
O&S Costs

- (H) High O&S Costs
- (M) Moderate O&S Costs
- (L) Low O&S Costs



The stakeholder value scatterplot synthesizes data to show each system alternative's response in dimensions of stakeholder value (unit cost, O&S cost, performance, development risk, growth potential)

Relative Feature Priority / Value Functions



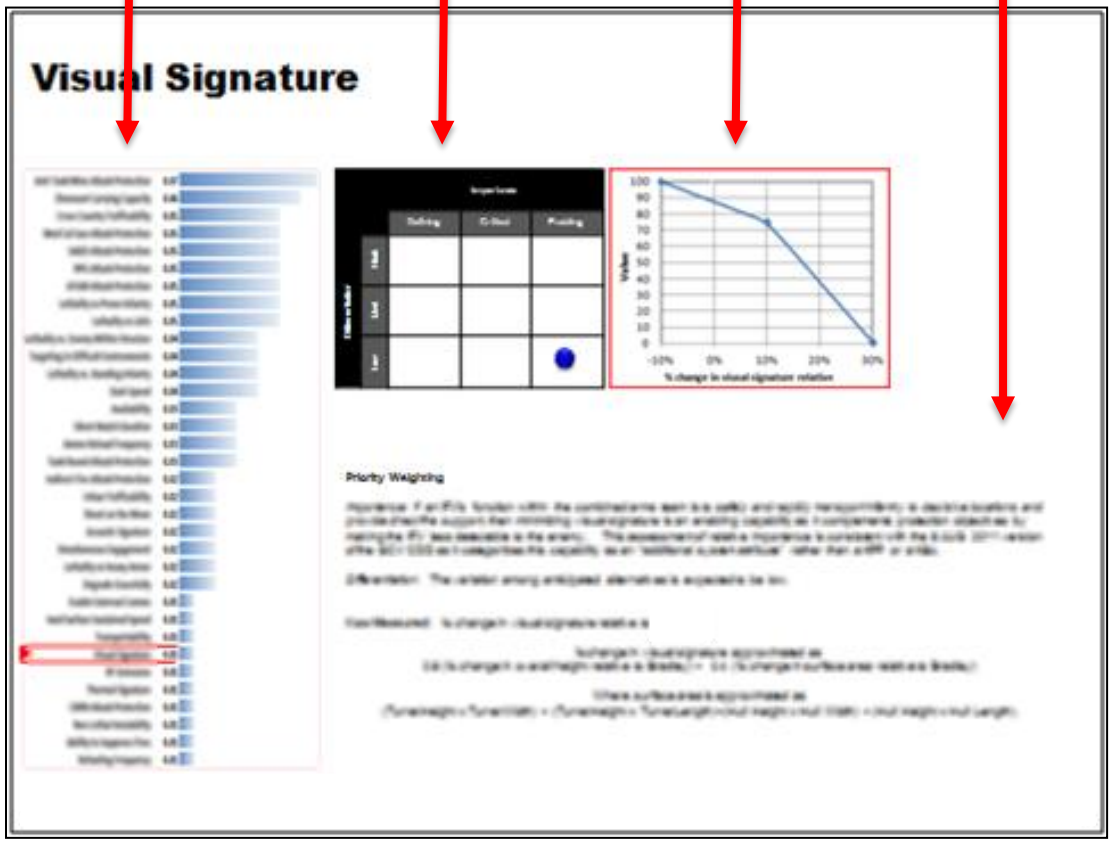
Priority weightings and value functions for each objective are well reasoned based on SME input and gaming data.

Relative Priority Weighting Indicator

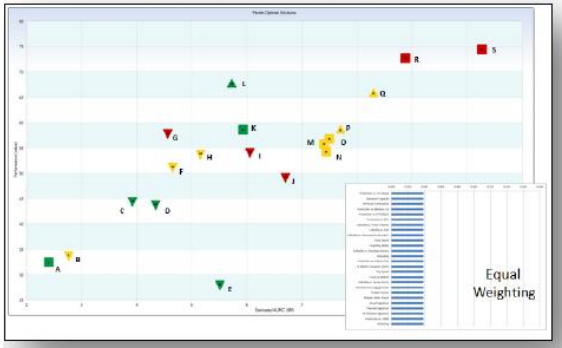
Swing Weight Matrix (Performance Gap vs. Importance)

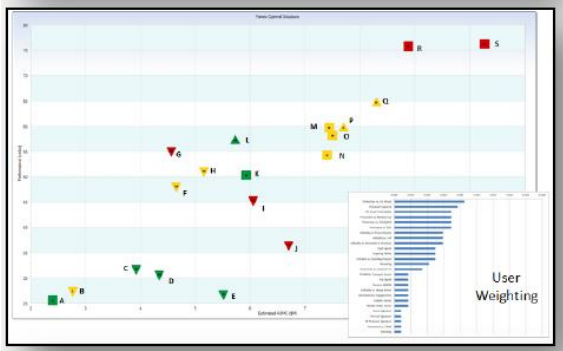
Value Function (knee in the curve)

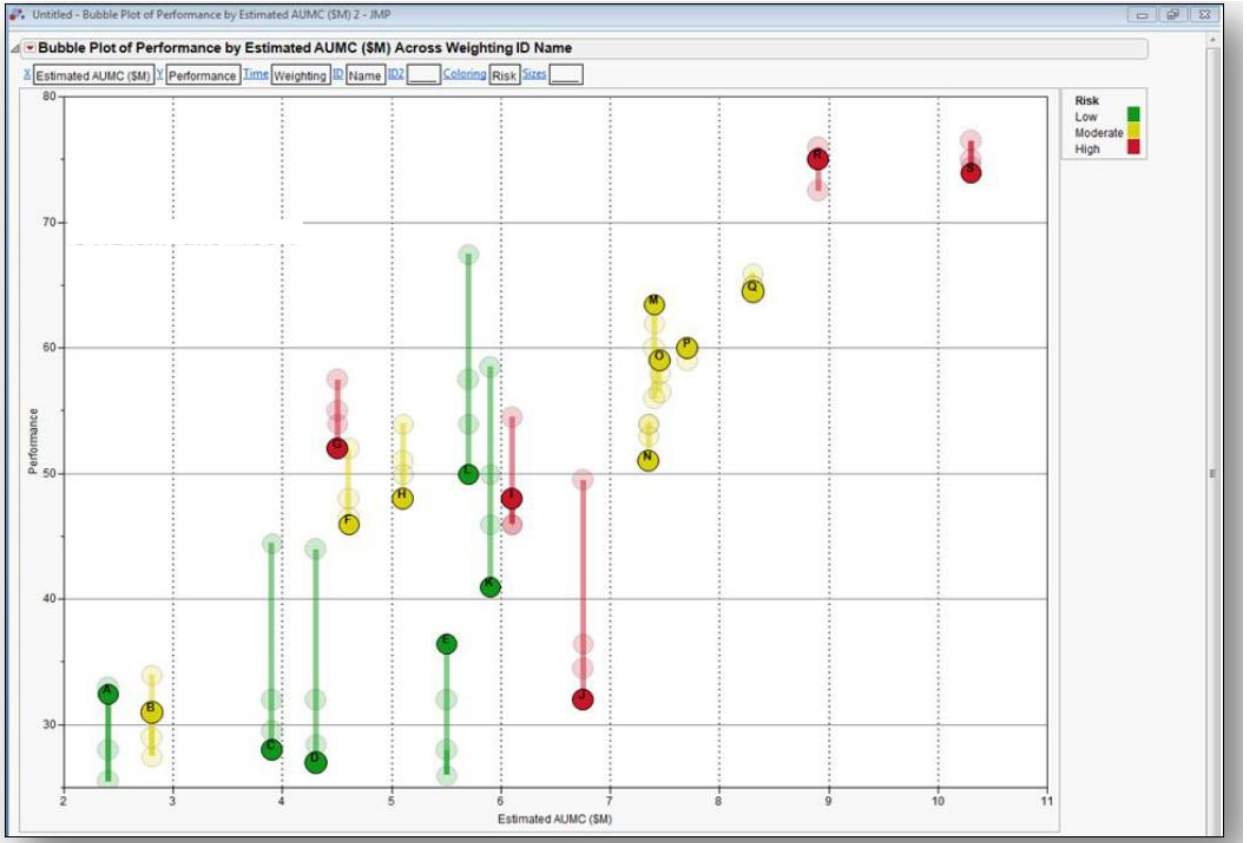
Supporting Narrative



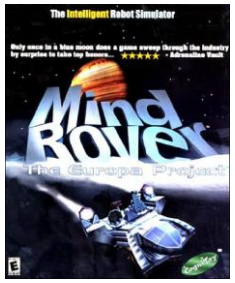
Sensitivity Analysis







Sensitivity analysis allows decision makers to see how performance values for each alternative move as priority weightings change.



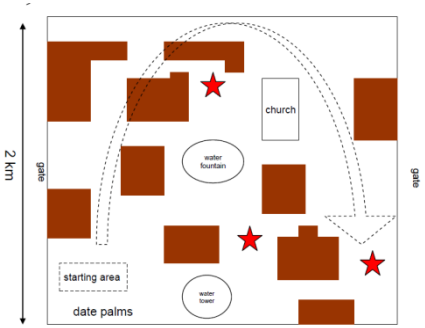
ESP Crowdsourced Demonstrator: Defense Acquisition University's MINDROVER / DRAGONFLY

- PMT-352 Program Management teaching tool
- Ver 1: Mindrover based on commercial game
- Ver 2: Dragonfly simplifies the "wiring requirements" and tunes for teaching
- MAJ Keena example DOE using MindRover

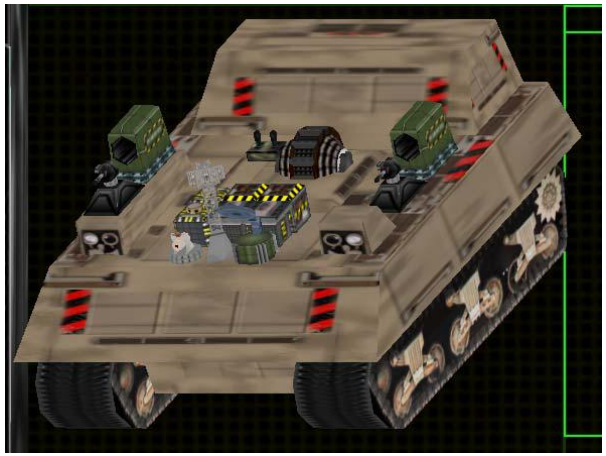
JRATS = (Joint Reconnaissance and Targeting System) robotic combat vehicle

Keena Study: Over 1400 MindRover Runs Using 14 ROTC Cadets

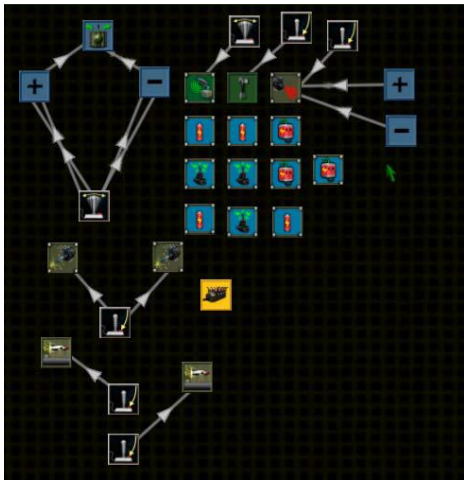
Move to Contact Urban Scenario



JRATS screenshot during contact. In this shot, the guided missile has drifted left of the laser and has missed the threat vehicle.



JRATS vehicle rendering of a completed tracked combat platform.



Design screen: Build components are placed on a virtual breadboard. Logic components and interface modules are wired together to form the functional combat platform prototype..

Very similar to SysML or DARPAs AVM META!

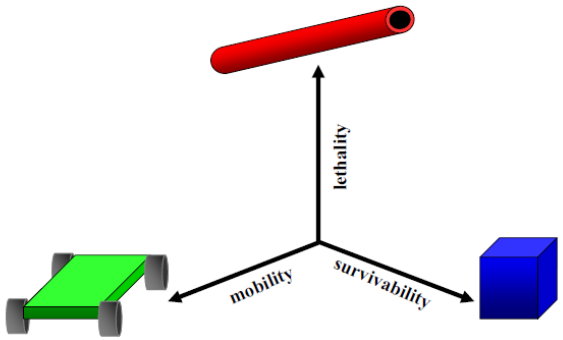
Source: "Demonstration of Decision Support Tools for Evaluating Ground Combat System Survivability, Lethality, and Mobility at the Tactical, Operational, and Strategic Levels of War." MAJ Joshua Keena PhD Dissertation. University of Texas as Austin, August 2011.

Keena's Game Based Design of Experiments

s Acceptable Survivability	S Enhanced Survivability
rolled homogeneous (steel) armor aluminum body	depleted uranium armor steel body

l Acceptable Lethality	L Enhanced Lethality
2× heavy machine gun laser range finder communications suite ground penetrating radar	2× guided missile pods 2× heavy machine gun laser range finder communications suite ground penetrating radar

m Acceptable Mobility	M Enhanced Mobility
low output powerplant aluminum frame	high output powerplant composite frame



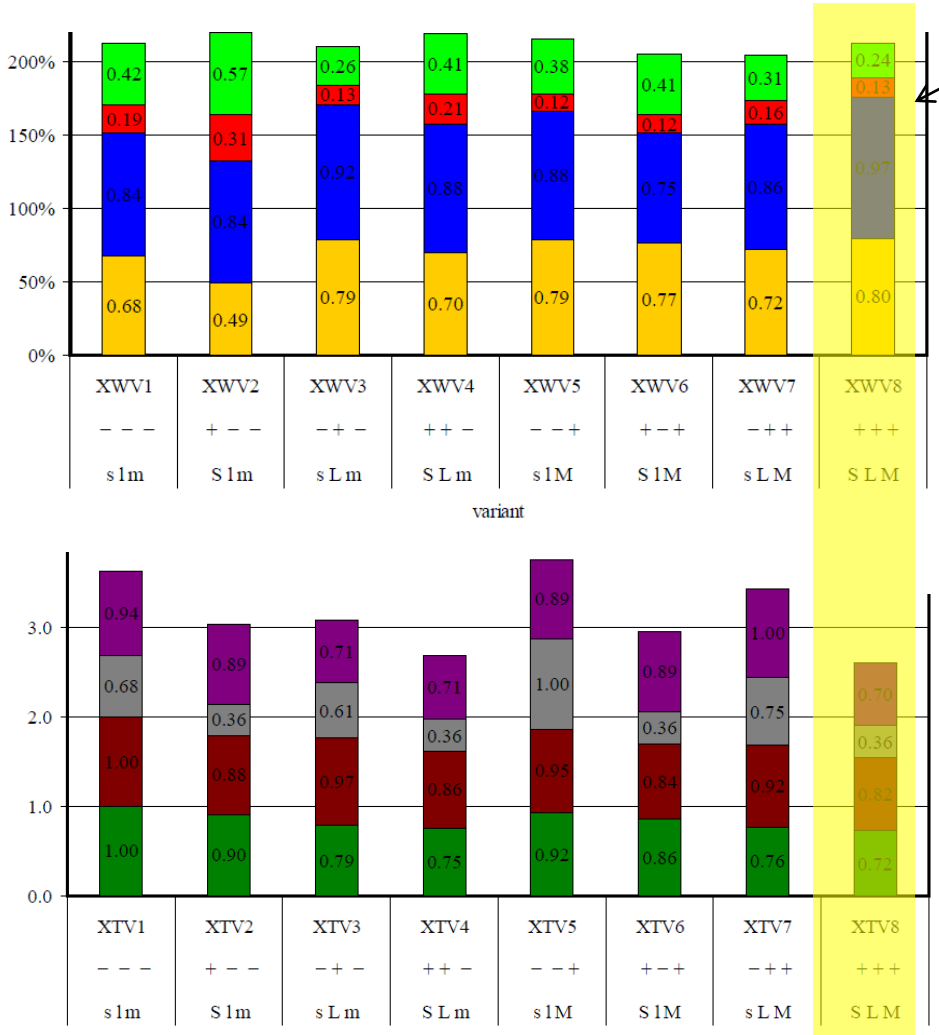
- DOE with 18 variants
  - tracked vs wheeled
  - survivability 2 levels
  - lethality 2 levels
  - mobility 2 levels
  - 2 training vehicles
- 14 Operators
  - 15 missions per randomly assigned variants
  - Result=~100 missions per vehicle
- 1600 ground vehicle missions

OUTPUT METRICS:

- rating of success or failure
- elapsed mission time (time mission)
- the friendly vehicle's remaining health (blue mission %)
- and threat vehicle's remaining health (red mission %)

Source: "Demonstration of Decision Support Tools for Evaluating Ground Combat System Survivability, Lethality, and Mobility at the Tactical, Operational, and Strategic Levels of War." MAJ Joshua Keena PhD Dissertation. University of Texas as Austin, August 2011.

Example Output Data
(Could be weighted/ normalized multiple ways)



Highest tactical performance per cost/mass/schedule/etc

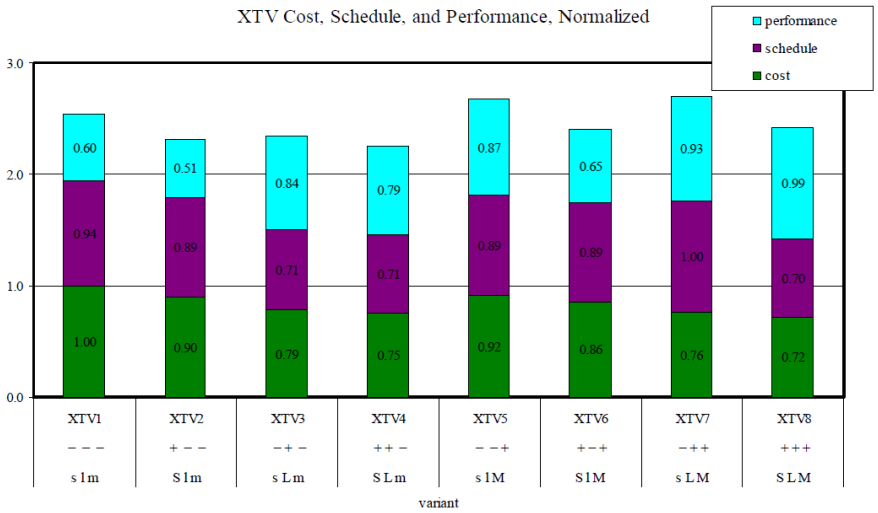
time %
red %
blue %
win %

schedule
volume
mass
cost

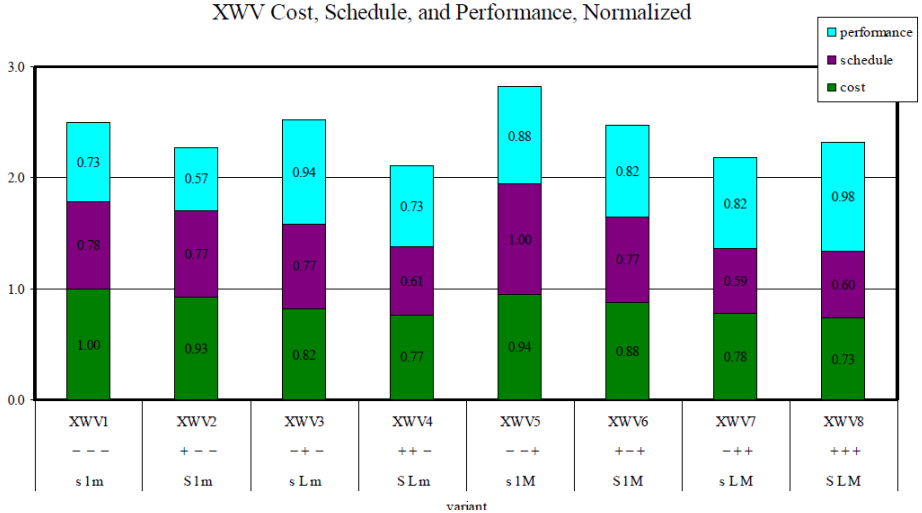
Source: "Demonstration of Decision Support Tools for Evaluating Ground Combat System Survivability, Lethality, and Mobility at the Tactical, Operational, and Strategic Levels of War." MAJ Joshua Keena PhD Dissertation. University of Texas as Austin, August 2011.

Example Output Data
(Here's normalized performance, schedule, and cost)

Tracked



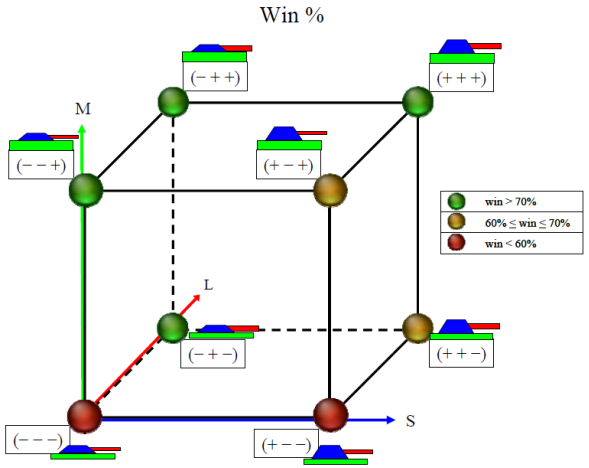
Wheeled



Performance is the sum of the normalized values for variant win %, blue %,red %, and time % divided by the number of *a posteriori metrics (4). Cost is* the per vehicle cost normalized with respect to the variant with the lowest per vehicle cost. Schedule is the normalized schedule index with respect to the variant with the lowest schedule index.

Source: "Demonstration of Decision Support Tools for Evaluating Ground Combat System Survivability, Lethality, and Mobility at the Tactical, Operational, and Strategic Levels of War." MAJ Joshua Keena PhD Dissertation. University of Texas as Austin, August 2011.

Relative Contributions and Interactions of Survivability, Lethality, and Mobility on Ground Combat Vehicle Performance



Average variant win record (XTV and XWV) in a survivability, lethality, and mobility domain. An XTV and XWV variant coincident at a point share the same relative levels of survivability, lethality, and mobility.

	Win % [%]	Blue % [%]	Red % [%]	Time % [%]
XTV	L 26	L 9	L 15	L 19
	M 19	S 2	M 13	M 12
	S 10	M 1	S 10	S 1
XWV	M 14	L 8	M 8	L 14
	L 8	S 2	S 4	M 8
	S 7	M 1	L 3	S 7

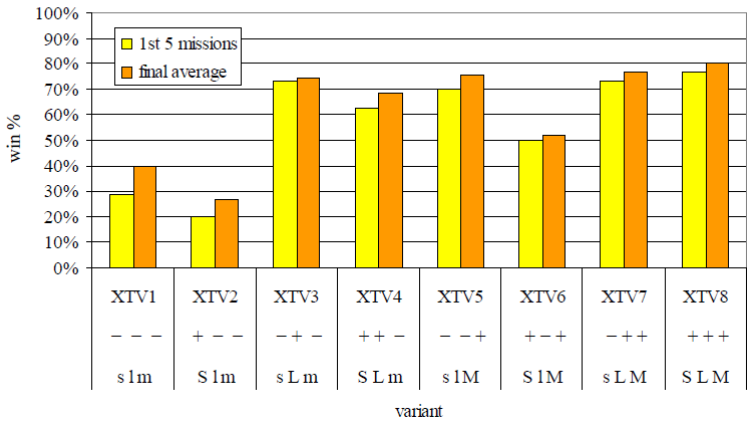
Effects of principal attributes on *a posteriori performance metrics for XTVs* and XWVs. A red bar indicates a negative effect on the metric, and a green bar indicates a positive effect on the metric. The length of the bar has been scaled in length with respect to the greatest effect for that metric in the XTV or XWV block.

Source: "Demonstration of Decision Support Tools for Evaluating Ground Combat System Survivability, Lethality, and Mobility at the Tactical, Operational, and Strategic Levels of War." MAJ Joshua Keena PhD Dissertation. University of Texas as Austin, August 2011.

Learning Rate Vs. AI

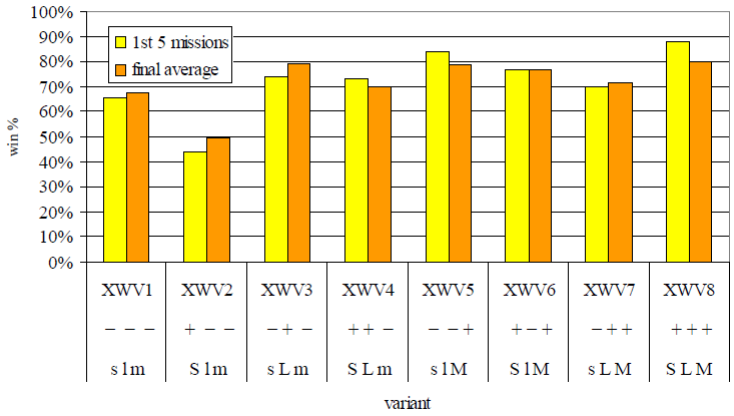
- During training sessions group discussed tactics, techniques, and procedures (TTPs)
- Training missions conducted on tracked and wheeled training vehicle variants (TTV and TWV)
- Operators instructed to move in a clockwise fashion until the enemy vehicle was spotted
- Non-training sessions Win % calculated after just 5 missions versus final average at 15 missions per operator

TRACKED



- Enhanced survivability platform had the greatest learning curve
  - Variant had the lowest mobility performance, with no gain in lethality
  - Operators presumably struggled initially to maneuver around the city
- Aside from the baseline variant (XTV1), all other variants had a learning curve less than 3%.

WHEELED

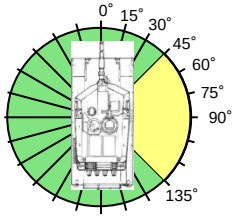


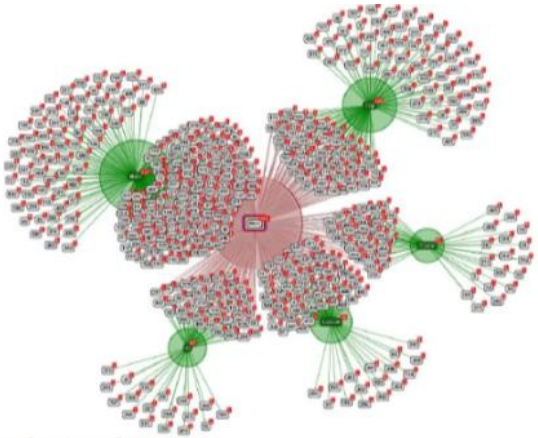
- Enhanced survivability platform had the greatest learning curve
  - Variant had the lowest mobility performance, with no gain in lethality
  - Operators presumably struggled initially to maneuver around the city
- Degradation in performance over time was seen for some variants
  - XWV8 experienced an over 5% drop in win % from first five to final 15 average
  - Possibly elevated baseline mobility enhanced even more for XWV5 and XWV8, caused operators to move in an ineffective or more "sloppy"
  - Suggests that the platform performance is directly effected by operators.

Source: "Demonstration of Decision Support Tools for Evaluating Ground Combat System Survivability, Lethality, and Mobility at the Tactical, Operational, and Strategic Levels of War." MAJ Joshua Keena PhD Dissertation. University of Texas as Austin, August 2011.

What Other Useful Metrics Might be Collected From Game Analytics?

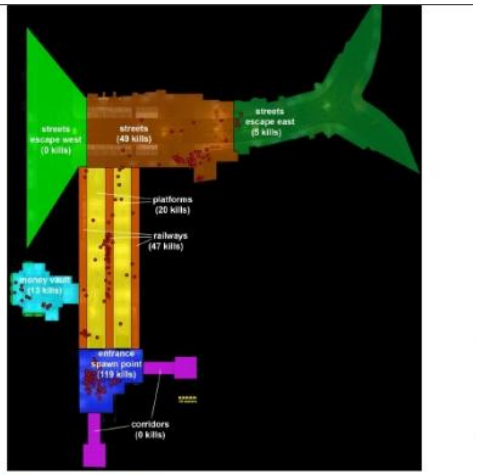
- Replays of winning tactics (directly obtained CONOPS)
- Discussion board chatter
- Sector engaged from in azimuth around vehicle
- Rounds expended
- How much available power and speed actually used





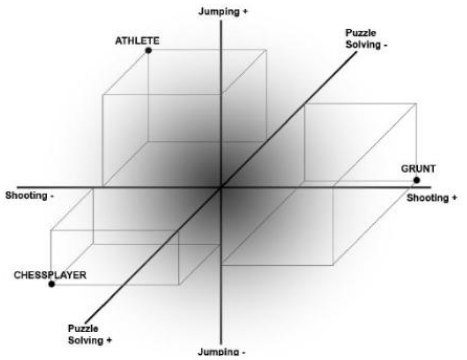
Flower of Death

Generated by a cluster visualization tool (shows data from *Fragile Alliance*, it relates ***role*** *at death* with ***cause*** *of death*)



Deaths in Sectors

Plotted deaths divided per sub-sector



Play persona possibility space

Mapping the possibility space with play-personas

Lower images from: http://www.slideshare.net/acagamic/game-metrics-and-biometrics-the-future-of-player-experience-research

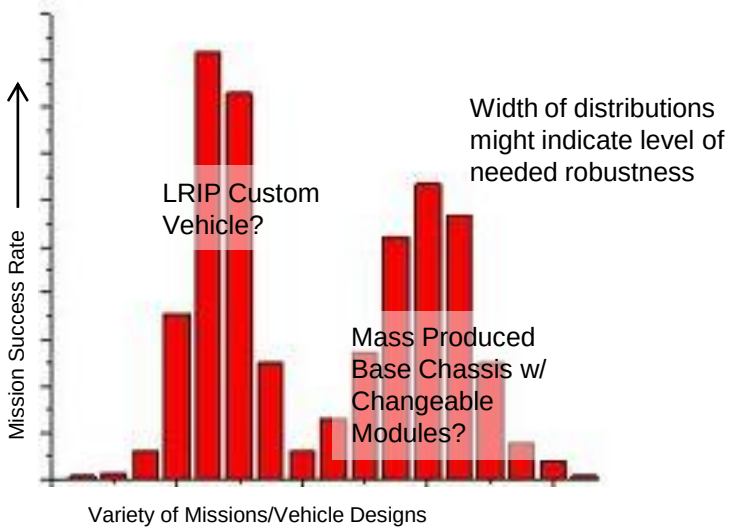
Enough Game Data Allows The Teasing Apart of Modularity and Customization Needs

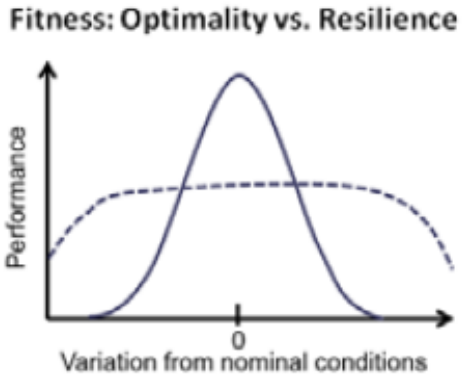
Which configuration elements can remain constant?

Which things need to be made modular?

Can a whole custom system be fabricated less expensively than a changeable system?

How robust is the solution in different scenarios?





Defense Acquisition University's DRAGONFLY Screenshots

- Dragonfly simplifies the "wiring requirements" and tunes for teaching
- Gives some clues as to complexity in a game for acquisitions

DragonFly ScreenShots (Formerly MindRover)

Parameters Tracked in Dragonfly

Chassis	FRACU	Scorpion	Mole
Vehicle Type	*Hover*	*Tracked*	*Wheeled*
Vehicle Size	*Small*	*Medium*	*Large*
Engine Size	Small	Medium	Large
Frame	Aluminum	Aluminum	Titanium
Armor	None	None	Steel

	Qty	Type	Qty	Type	Qty	Type
Power	3	Mk-III Batteries	1	Mk-V Battery	2	Mk-IV Generators
			1	Mk-III Fuel Cell	1	Mk-I Battery
			1	Mk-IV Generator		

	Qty	Type	Qty	Type	Qty	Type
Electronic Components	1	Mk-I Targeting Laser	1	Mk-IV Targeting Laser	1	Mk-IV Targeting Laser
	1	Mk-I Radio Transmitter	1	Mk-IV Radio Transmitter	1	Mk-IV Radio Transmitter
	1	Mk-I Linear Mine Detector	1	Mk-V Linear Mine Detector	1	Mk-IV Hemispherical Mine Detector
	1	Mk-I Radar	1	Mk-I Radar	1	Mk-IV Radar
	1	Mk-I Targeting Computer	1	Mk-I Targeting Computer	1	Mk-IV Targeting Computer
			1	Mk-IV Electronic Countermeasure	1	Mk-IV Electronic Countermeasure

	Qty	Type	Qty	Type	Qty	Type
Weapons	1	Mk-I Mini Gun	1	Mk-I Machine Gun	2	Mk-IV Mini Guns
	1	Mk-I Laser Guided Missile	1	Mk-I Laser Guided Missile	1	Mk-IV Free Rocket
			1	Mk-I Multi-Shot Free Rocket	1	Mk-IV Multi-Shot Free Rocket

Properties	FRACU	Scorpion	Mole
Weight (kg)	1266	1485	2029
Combat Survivability	230	275	410
Idle Power (watts)	35	58	59
Active Power (watts)	97	135	142
Produced Power (watts)	105	135	125
Acceleration (m/sec^2)	8	7	9
Top Speed (kph)	25	14	30
Length (m)	2.25	3	3
Logistics Supportability Index (LSI)	**2866**	**3085**	**3629**
Deployability Index (DI)	**1741**	**1960**	**2504**
Producibility Index (PI)	**830**	**875**	**1010**

Costs			
Development	$41M	$60.5M	$86.5M
O&S	$1230M	$1710M	$2370M
Procurement	$615M	$855M	$1185M
Unit Procurement	**$0.41M**	**$0.57M**	**$0.79M**
Disposal	$61.5M	$85.5M	$118.5M
MILPERS	$184.5M	$256.5M	$355.5M
Total	**$2132M**	**$2967.5M**	**$4115.5M**

DragonFly ScreenShots

DragonFly ScreenShots

DragonFly ScreenShots

Vehicle Configuration

Virtual Field Test

"Mission Load" screen for "Field Test" test mode

Field Reports

Conclusions

- Pilot studies indicate it is possible to get useful data from virtual combat (i.e. games)
  - Have only scratched the surface on true utility of this
- 21st Century Blitzkrieg requires tactics and materiel be tightly coordinated
  - Alternative is 21st century Maginot Line
- Crowdsourced gaming might provide enough data to allow acquisitions to understand growth, modularity, and maybe custom vehicle needs
  - Maximize tooth, minimize tail